Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Length-weight relationships of fish from sandy beaches

Relação peso-comprimento de 16 espécies de peixes que ocorrem perto de praias arenosas ao longo da bacia do baixo rio Negro na Amazônia brasileira

D. Olentino[a]*, C. C. F. Lubich[b], M. D. P. Rocha[a], J. H. N. Santos[a], T. Gomes[a], H. Beltrão[c], J. F. Silva[d] and K. C. Yamamoto[e]

[a]Universidade Federal do Amazonas – UFAM, Programa de Educação Tutorial de Engenharia de Pesca – PET Pesca, Manaus, AM, Brasil
[b]Universidade Federal do Amazonas – UFAM, Programa de Pós-graduação em Ciência Animal e Recursos Pesqueiros, Laboratório de Ecologia Pesqueira – LABEP, Manaus, AM, Brasil
[c]Universidade Federal do Amazonas – UFAM, Programa de Pós-graduação em Ciências Pesqueiras nos Trópicos, Manaus, AM, Brasil
[d]Universidade Federal do Amazonas – UFAM, Laboratório de Ictiologia – LABIC, Manaus, AM, Brasil
[e]Universidade Federal do Amazonas – UFAM, Departamento de Ciências Pesqueiras, Laboratório de Ictiologia – LABIC, Manaus, AM, Brasil

Abstract

This study estimated the length–weight relationships of 16 fish species occurring close to the shores of sandy beaches along the lower Negro River basin, Brazilian Amazon. The specimens were captured for one day each month, in October to November 2016, early in the morning and early evening, using trawl net (20 m length and 3.5 m height, 5 mm mesh between opposite knots). Measurements were taken for standard length (SL – 0.1 cm precision) and total weight (TW – 0.01 g precision). The parameters *a* and *b* of the equation $WT = a.LT^b$ were estimated. The *a* values ranged from 0.0018 to 0.0226 and *b* values ranged from 2.5271 to 3.3244. This study also provides new data on of maximum lengths for six species, *Amazonsprattus scintilla, Brycon pesu, Moenkhausia megalops, Pachyurus paucirastrus, Reganella depressa* and *Trachydoras microstomus*, and new reports of the LWRs parameters of 15 fish species.

Keywords: ichthyofauna, sandy beach, allometric coefficient, allometry.

Resumo

Este estudo estimou as relações comprimento-peso de 16 espécies de peixes que ocorrem às margens de praias arenosas ao longo da bacia do baixo Rio Negro, Amazônia brasileira. As espécies foram capturadas durante um dia de cada mês, de outubro a novembro de 2016, no início da manhã e no início da noite, usando rede de cerco (20 m de comprimento e 3,5 m de altura, 5 malha mm entre nós opostos). As medidas foram feitas para comprimento padrão (SL - precisão de 0,1 cm) e peso total (TW - precisão de 0,01 g). Os parâmetros *a* e *b* da equação $WT = a.LT^b$ foram estimados. Os valores de *a* variaram de 0,0018 a 0,0226 e os valores de *b* variaram de 2,5271 a 3,3244. Este estudo também fornece novos dados sobre comprimentos máximos para seis espécies, *Amazonsprattus scintilla, Brycon pesu, Moenkhausia megalops, Pachyurus paucirastrus, Reganella depressa* e *Trachydoras microstomus*, e novos reportes dos parâmetros da LWRs de 15 espécies de peixes.

Palavras-chave: ictiofauna, praia, coeficiente alométrico, alometria.

1. Introduction

The Negro River is one of the main tributaries of the Amazon River (Junk et al., 2015), and its diversity of fish is among the richest so far reported in the world (Roberts, 1972; Saint-Paul et al., 2000; Soares and Yamamoto, 2005). As such, it is of major importance to the region, with species with great ornamental (Olentino et al., 2020) and commercial (Inomata and Freitas, 2018) potential, as well as for recreational fisheries (Furtado, 2020; Campos et al., 2020).

Currently 1165 species are known, with high levels of endemism (Beltrão et al., 2019), and these are distributed in various aquatic environments, such as flooded forests (*igapós*), alluvial island lakes, wooded shore areas, swamps and sandy beaches (Goulding et al., 1988).

The sandy beaches deserve a special mention since they are subjected to the flood pulse. These areas are susceptible to flooding during periods of high water and contribute to the migration of fish species, while in the low water period the areas close to their shores are key shallow aquatic environments due to their provision of shelter for many species (Goulding et al., 1988, Goulding,

*e-mail: daniel.olentino@gmail.com
Received: March 17, 2021 – Accepted: June 9, 2021

1997; Claro-Junior, 2007; Olds et al., 2018). However, are scarce in the literature studies on the regarding the length–weight relationships species that occur close to the shores of the sandy beaches along the Rio Negro basin.

This length–weight relationships, is useful in fisheries and species monitoring, also serve as baseline data for future studies focused on the as for programs conservation, and ecology of natural resources in the region. The present study describes the LWRs parameters of 16 fish species collected close to sandy beaches along the lower Negro River basin in the Brazilian Amazon.

2. Materials and Methods

Sampling was conducted near three sandy beaches located in the Anavilhanas National Park - PARNA (municipality of Novo Airão) and Reserva de Desenvolvimento Sustentável Tupé – RDS Tupé (municipality of Manaus) (Figure 1). The Anavilhanas National Park and RDS Tupé are bordered by the typical black waters of the Negro River basin, rich in dissolved humic substances, acidic pH and low sediment load. They have a transparency that varies between 1.3 and 1.5 m (Latrubesse and Stevaux, 2015; Sioli, 1984).

Along the lower Negro River, sandy substrates dominate at lower topographic levels-and, in the dry season, possible to see large stretches of sandy beaches emerging (Junk et al., 2015; Latrubesse and Stevaux, 2015). These environments lead to the creation of thousands of kilometers of habitats that are occupied by fish communities searching for food and shelter to survive (Goulding et al., 1988).

For the sampling, we used a trawl net (20 m length and 3.5 m height, 5 mm mesh between opposite knots) to collect the specimens. Fish were sampled for one day each month, in October to November 2016. Five parallel trawls were carried out on each beach during in the morning (about 7–10 a.m.) and five at night (about 6–7 p.m.), totaling 30 samplings (Ferreira et al., 1998; Zuanon et al., 2015) and advice from specialists.

Subsequently, were used Eugenol for euthanasia (as recommended by American Veterinary Medical Association - Leary et al., 2020). Fresh fish were submitted to biometrics to measure the total weight (nearest 0.01 g total weight, W) and standard length (nearest 0.1 cm standard length, L) and preserved in 10% formalin. Samples were collected under the license SISBIO 50778-1.

The length–weight relationship of the species ware obtained using non-linear regression and the Levenberg-Marquardt algorithm (Lourakis, 2005), using the equation: $W=a.L^{b}$ (Le Cren, 1951), where W is the total weight (g), L is the standard length, *a* is the intercept and *b* is the allometric coefficient. The confidence limit (CL) of 95% was determined for parameters *a* and *b* (Froese, 2006). All outliers were identified and removed from the analysis (Froese, 2006).

3. Results

A total of 2677 individuals from 16 species belonging to five orders, and 10 families were analyzed. The LWR parameters of the species, sample size, minimum and maximum length and weight for each species are shown in Table 1.

All regressions were significant for all the species ($p < 0.05$), with the coefficient of determination r^2 ranging from 0.9512 to 0.9998, and the *a* values ranging from 0.0018 to 0.0226 and *b* values ranging from 2.5271 to 3.3244.

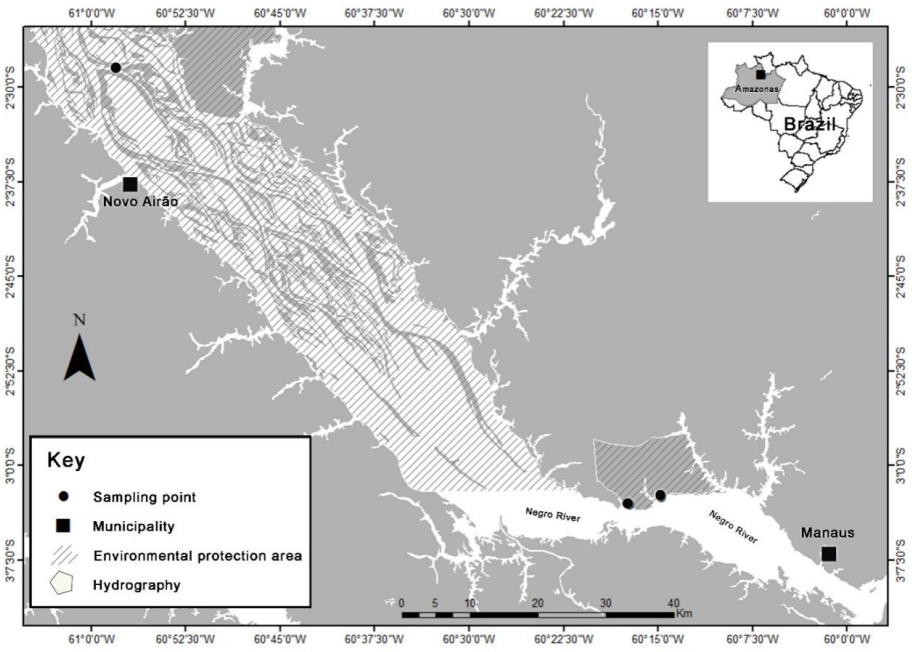

Figure 1. Map of the sampling points close to sandy beaches along the lower Negro River basin in the Brazilian Amazon.

Table 1. Length-weight relationship (LWR) parameters for samples of 16 fish species obtained close to sandy beaches along the lower Negro River basin in the Brazilian Amazon.

Order | Family | Species	N	Standard Length (cm)		Total Weight (g)		LWR parameters		
		Min.	Max.	Min.	Max.	*a* (95% CL)	*b* (95% CL)	r^2
Clupeiformes								
Engraulidae								
Amazonsprattus scintilla Roberts, 1984	590	1.3	2.3 [a]	0.01	0.1	0.0065 (0.0058 – 0.0072)	3.1376 (2.9917 – 3.2835)	0.9775
Anchoviella carrikeri Fowler, 1940	261	3.4	4.6	0.32	0.83	0.0078 (0.0070 – 0.0087)	3.0275 (2.9479 – 3.1070)	0.9946
Anchoviella juruasanga Loeb, 2012	28	1.7	4.2	0.07	4.2	0.0194 (0.0166 – 0.0223)[c]	2.5271 (2.4221 – 2.6321)[d]	0.9998
Characiformes								
Bryconidae								
Brycon pesu Müller & Troschel, 1845	44	1.4	13.9 [a]	0.05	13.9	0.0189 (0.0165 – 0.0213)	3.0225 (2.9708 – 3.0743)	0.9993
Characidae								
Moenkhausia megalops Eigenmann, 1907	306	1.8	5.4 [a]	0.1	4.69	0.0171 (0.0161 – 0.0181)	3.3244 (3.2789 – 3.3698)[c]	0.9889
Moenkhausia gracilima Eigenmann, 1908	272	2.8	3.9	0.3	3.9	0.0204 (0.0158 – 0.0250)	2.8083 (2.6259 – 2.9908)[d]	0.9512
Microschemobrycon melanotus Eigenmann, 1912	114	1.7	3.1	0.1	0.5	0.0140 (0.1131 – 0.0167)	3.1614 (2.9577 – 3.3651)	0.9739
Moenkhausia cotinho Eigenmann, 1908	40	2.8	4.0	0.4	1.3	0.0154 (0.0104 – 0.0204)	3.1936 (2.9460 – 3.4412)	0.9970
Microschemobrycon casiquiare Böhlke 1953	133	1.9	2.6	0.1	0.3	0.0141 (0.0118 – 0.0164)	3.1802 (2.9844 – 3.3760)	0.9794
Gymnotiformes								
Sternopygidae								
Eigenmannia macrops Boulenger, 1897[b]	346	4.6	11.5	0.4	4.4	0.0072 (0.0068 – 0.0077)	2.6212 (2.5923 – 2.6500)[d]	0.9972
Hypopomidae								
Steatogenys elegans Steindachner, 1880[b]	23	7.0	14.5	1.2	12.0	0.0033 (0.0029 – 0.0037)	3.0609 (3.0100 – 3.1119)	0.9997
Siluriformes								
Loricariidae								
Reganella depressa Kner, 1853	11	1.7	14.5 [a]	0.02	18.4	0.0018 (0.0011 – 0.0025)	3.2748 (3.1372 – 3.4124)	0.9994
Auchenipteridae								
Ageneiosus uranophthalmus Ribeiro & Rapp Py-Daniel, 2010[b]	49	4.0	8.9	0.7	6.86	0.0108 (0.0092 – 0.0125)	2.9424 (2.8665 – 3.0183)	0.9990
Doradidae								
Trachydoras microstomus Eigenmann, 1912	300	1.9	6.7 [a]	0.2	7.1	0.0191 (0.0180 – 0.0203)	3.0807 (3.0436 – 3.1179)	0.9886

Key: N = sample size; *a* = intercept; *b* = slope; r^2 = coefficient of determination of the length-weight relationship; 95% CL = 95% confidence limit. [a] New maximum standard length; [b] Provisional estimate: Sample size is limited and perhaps the smaller size classes are over-represented; [c] Value above 95% confidence limits of the Bayesian prediction; [d] Value below 95% confidence limits of the Bayesian prediction.

Table 1. Continued...

Order | Family | Species	N	Standard Length (cm)		Total Weight (g)		LWR parameters		
		Min.	Max.	Min.	Max.	*a* (95% CL)	*b* (95% CL)	r^2
Perciformes								
Sciaenidae								
Pachyurus paucirastrus Aguilera, 1983	130	1.3	15.0 [a]	0.02	63.0	0.0117 (0.0090 – 0.0143)	3.1646 (3.0777 – 3.2515)	0.9898
Cichliformes								
Cichlidae								
Apistogramma pulchra Kullander, 1980	30	1.5	3.0	0.08	0.7	0.0220 (0.0177 – 0.0262)	3.2431 (3.0315 – 3.4547)	0.9935

Key: N = sample size; *a* = intercept; *b* = slope; r^2 = coefficient of determination of the length-weight relationship; 95% CL = 95% confidence limit. [a] New maximum standard length; [b] Provisional estimate: Sample size is limited and perhaps the smaller size classes are over-represented; [c] Value above 95% confidence limits of the Bayesian prediction; [d] Value below 95% confidence limits of the Bayesian prediction.

Based on the values obtained from the Bayesian predictions available on FishBase (Froese and Pauly, 2021), four species had a and b values outside the 95% confidence limit (Table 1). The present study provides new information on the maximum length for the following six species: *Amazonsprattus scintilla, Brycon pesu, Moenkhausia megalops, Pachyurus paucirastrus, Reganella depressa* and *Trachydoras microstomus*.

4. Discussion

Areas close to sandy beaches include mainly species of Characiformes and Siluriformes of small size with low migration capacities over great distance (Claro-Junior, 2007, Duarte et al., 2010). During the low water period, more than 100 species of fish can be found, and these mainly have well-developed eyes and feed on small invertebrates living on the sandy river bed (Goulding et al., 1988; Goulding, 1997).

The 16 species presented a coefficient of determination (r^2) within the acceptable value (95%) and the values of b fell within the expected range of 2.5–3.5 (Froese, 2006). In the Bayesian LWR predictions, four species had *a* or *b* or both values outside the 95% confidence limits (Table 1) (Froese and Pauly, 2021). This is because the LWR estimates were based on data for similar body shape and total length for each taxon (Froese et al., 2014; Froese and Pauly, 2021).

The LWR estimates for *Brycon pesu* can be found in other studies (Giarrizzo et al., 2011), however, we chose to maintain this species in our study since it reports a new maximum length and presents a larger number of specimens. However, for the other species this is the first report with these estimates.

The data for *Ageneiosus uranophthalmus* (max length: 23.0 cm SL_{max}, see Ribeiro and Py-Daniel, 2010), *Eigenmannia macrops* (25.2 cm TL_{max}, see Albert, 2003a) and *Steatogenys elegans* (max length: 29.4 cm TL_{max}, see Albert, 2003b) cover a limited size range, therefore approximately 50% of the TL_{max} is included in the analysis, and the classes of sizes may be over-represented. The parameters of the equation (*a* and *b*) may be influenced by juvenile individuals, since they have different growth patterns to adults and the point at which they transition from juveniles to adults has not yet been determined (Olentino et al., 2021). Similar provisional estimates have been reported before for *Moenkhausia lata* (Olentino et al., 2021), which is a species that also occurs in the Negro River basin.

In our study, small species occur, however, the species *Amazonsprattus scintilla* was the only one that presented a weight that was at the precision limit of the scale (0.01 g). Olentino et al. (2021) cite problematic issues related to the measurement of the weight of small species, thus care must be taken, such as the use of more accurate equipment (scales that are accurate to 0.001 g) and limiting the time of exposure of individuals to air, due to weight loss through evaporation, in order to guarantee the quality and reliability of the data.

Finally, this study provides the first information on LRW parameters for 15 Neotropical fish species, and presents data that can contribute to future studies focused regional management of the basin and for species conservation.

Acknowledgements

We are indebted to the Programa de Educação Tutorial de Engenharia de Pesca, PET-Pesca/UFAM, to the Universidade Federal do Amazonas and to the Fundo Nacional de Desenvolvimento da Educação (FNDE).

References

ALBERT, J.S., 2003a. Sternopygidae (Glass knifefishes, Rattail knifefishes). In R.E. REIS, S.O. KULLANDER and C.J. FERRARIS JUNIOR, editors. *Checklist of the Freshwater Fishes of South and Central America*. Porto Alegre: EDIPUCRS, pp. 487-491.

ALBERT, J.S., 2003b. Hypopomidae (Bluntnose knifefishes). In: R.E. REIS, S.O. KULLANDER and C.J. FERRARIS JUNIOR, editors. *Checklist of the Freshwater Fishes of South and Central America*. Porto Alegre: EDIPUCRS, pp. 494-496.

BELTRÃO, H., ZUANON, J. and FERREIRA, E., 2019. Checklist of the ichthyofauna of the Rio Negro basin in the Brazilian Amazon. *ZooKeys*, vol. 881, pp. 53-89. http://dx.doi.org/10.3897/zookeys.881.32055. PMid:31662611.

CAMPOS, C.P., CATARINO, M.F. and FREITAS, C.E.C., 2020. Stock assessment of the peacock bass Cichla temensis (Humboldt, 1821), an important fishing resource from the middle Negro river, Amazonas, Brazil. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 80, no. 3, pp. 506-510. http://dx.doi.org/10.1590/1519-6984.203124. PMid:31576929.

CLARO-JUNIOR, L.H., 2007. *Distribuição e estrutura trófica das assembleias de peixes em praias do Rio Solimões/Amazonas, Brasil*. Manaus: INPA, 89 p. Tese de Doutorado em Biologia em Água Doce e Pesca Interior.

DUARTE, C., PY-DANIEL, L.R. and DEUS, C.P.D., 2010. Fish assemblages in two sandy beaches in lower Purus river, Amazonas, Brazil. *Iheringia. Série Zoologia*, vol. 100, no. 4, pp. 319-328. http://dx.doi.org/10.1590/S0073-47212010000400006.

FERREIRA, E.J.G., ZUANON, J.A.S. and SANTOS, G.M., 1998. *Peixes comerciais do médio Amazonas: região de Santarém, Pará*. Brasília: IBAMA, 214 p.

FROESE, R. and PAULY, D., 2021 [viewed 10 February 2021]. *FishBase* [online]. Available from: https://www.fishbase.org

FROESE, R., 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *Journal of Applied Ichthyology*, vol. 22, no. 4, pp. 241-253. http://dx.doi.org/10.1111/j.1439-0426.2006.00805.x.

FROESE, R., THORSON, J.T. and REYES JUNIOR, R.B., 2014. A Bayesian approach for estimating length-weight relationships in fishes. *Journal of Applied Ichthyology*, vol. 30, no. 1, pp. 78-85. http://dx.doi.org/10.1111/jai.12299.

FURTADO, C.L.C., 2020. *Efeito da pesca comercial e esportiva sobre os "troféus" de tucunaré-açu (Cichla temensis, Humboldt, 1821) em um trecho do médio Rio Negro, Barcelos-Amazonas*. Manaus: INPA, 86 p. Dissertação de Mestrado em Biologia em Água doce e Pesca Interior.

GIARRIZZO, T., BASTOS, D. and ANDRADE, M., 2011. Length-weight relationships for selected fish species of Rio Trombetas Biological Reserve: a reference study for the Amazonian basin. *Journal of Applied Ichthyology*, vol. 27, no. 6, pp. 1422-1424. http://dx.doi.org/10.1111/j.1439-0426.2011.01820.x.

GOULDING, M., 1997. *História natural dos rios amazônicos*. Tefé: Sociedade Civil Mamirauá.

GOULDING, M., CARVALHO, M.L. and FERREIRA, E.J.G., 1988. *Río Negro, rich life in poor water: Amazonian diversity and foodchain ecology as seen through fish communities*. The Hague (Netherlands): PB Academic Pub.

INOMATA, S.O. and FREITAS, C.E.C., 2018 [viewed 10 February 2021]. Fishing in the middle Rio Negro: socioeconomic aspects and operational structure. *Boletim do Instituto de Pesca* [online], vol. 41, no. 1, pp. 79-87. Available from: https://www.pesca.sp.gov.br/boletim/index.php/bip/article/view/41_1_79-87

JUNK, W.J., WITTMANN, F., SCHÖNGART, J. and PIEDADE, M.T.F., 2015. Uma classificação dos principais habitats das planícies aluviais dos rios de águas negras da Amazônia e uma comparação com suas contrapartes de águas brancas. *Wetlands Ecology and Management*, vol. 23, no. 4, pp. 677-693. http://dx.doi.org/10.1007/s11273-015-9412-8.

LATRUBESSE, E.M. and STEVAUX, J.C., 2015. The anavilhanas and mariuá archipelagos: fluvial wonders from the Negro River, Amazon Basin. In: B. VIEIRA, A. SALGADO and L. SANTOS, editors. *Landscapes and Landforms of Brazil*. Dordrecht: Springer, pp. 157-169. http://dx.doi.org/10.1007/978-94-017-8023-0_14.

LE CREN, E.D., 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *Journal of Animal Ecology*, vol. 20, no. 2, pp. 201-219. http://dx.doi.org/10.2307/1540.

LEARY, S., UNDERWOOD, W., ANTHONY, R., CARTNER, S., GRANDIN, T., GREENACRE, C., GWALTNEY-BRANT, S., MCCRACKIN, M. A., MEYER, R., MILLER, D., SHEARER, J., TURNER, T. and YANONG, R., 2020. AVMA Guidelines for the Euthanasia of Animals: 2020 Edition. Meacham Road Schaumburg, IL: American Veterinary Medical association, 931 N.

LOURAKIS, M.I., 2005. A brief description of the Levenberg-Marquardt algorithm implemented by Levmar. *Foundation of Research and Technology*, vol. 4, no. 1, pp. 1-6.

OLDS, A.D., VARGAS-FONSECA, E., CONNOLLY, R.M., GILBY, B.L., HUIJBERS, C.M., HYNDES, G.A., LAYMAN, C.A., WHITFIELD, A.K. and SCHLACHER, T.A., 2018. The ecology of fish in the surf zones of ocean beaches: a global review. *Fish and Fisheries*, vol. 19, no. 1, pp. 78-89. http://dx.doi.org/10.1111/faf.12237.

OLENTINO, D., LUBICH, C.C.F. and YAMAMOTO, K.C., 2020 [viewed 10 February 2021]. Espécies de peixes com potencial ornamental nas proximidades de Manaus, Amazonas-Brasil. *Scientia Amazonia* [online], vol. 9, no. 4, pp. CA1-CA10. Available from: http://scientia-amazonia.org/wp-content/uploads/2020/11/v9-n4-CA1-CA10-2020.pdf

OLENTINO, D., LUBICH, C.C.F., LEAL, M.S. and YAMAMOTO, K.C., 2021. Length-weight relationship of six small fish species from the Negro River basin in the Brazilian Amazon. *Journal of Applied Ichthyology*, vol. 37, no. 3, pp. 492-496. http://dx.doi.org/10.1111/jai.14180.

RIBEIRO, F.R.V. and PY-DANIEL, L.H.R., 2010. Ageneiosus uranophthalmus, a new species of auchenipterid catfish (Osteichthyes: Siluriformes) from river channels of the central Amazon basin, Brazil. *Neotropical Ichthyology*, vol. 8, no. 1, pp. 97-104. https://doi.org/10.1590/S1679-62252010000100012.

ROBERTS, T.R., 1972. Ecology of fishes in the Amazon and Congo basins. *Bulletin of the Museum of Comparative Zoology at Harvard College*, vol. 143, pp. 117-147.

SAINT-PAUL, U., ZUANON, J., CORREA, M.A.V., GARCÍA, M., FABRÉ, N.N., BERGER, U. and JUNK, W.J., 2000. Fish communities in central Amazonian white-and blackwater floodplains. *Environmental Biology of Fishes*, vol. 57, no. 3, pp. 235-250. http://dx.doi.org/10.1023/A:1007699130333.

SIOLI, H., 1984. Introduction: history of the discovery of the Amazon and of research of Amazonian waters and landscapes. In: H. SIOLI, editor. *The Amazon* (pp. 1-13). Dordrecht: Springer. http://dx.doi.org/10.1007/978-94-009-6542-3_1.

SOARES, M.G.M., and YAMAMOTO, K.C., 2005. Diversidade e composição da ictiofauna do lago Tupé. In: E.N. SANTOS-SILVA, F.M. APRILE and V.V. SCUDELLER and S. MELO, organizadores. *Diversidade Biológica e Sociocultural do Baixo Rio Negro, Amazônia Central*. Manaus: Editora INPA, pp. 181-197.

ZUANON, J., MENDONÇA, F.P., SANTO, H.M.V.E., DIAS, M.S., GALUCH, A.V. and AKAMA, A., 2015. *Guia de peixes da Reserva Adolpho Ducke*. Manaus: Editora INPA.